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(54) Optical fibre telecommunications line with separate service channels.

(57) The invention refers to an optical fibre transmission line which comprises means (9, 10) for injecting and means (9, 10) for extracting optical service signals from the line' s optical fibre (3), where said means comprise emission and/or reception units (10) of optical service signals, suitable for receiving from the optical line (3) and/or emitting towards the line itself service signals in the form of optical signals having a wavelength which is substantially different from the wavelength of the telecommunications signals, each of which units (10) is associated with a corresponding optical coupler (9) inserted along the line (3), suitable for coupling within the line fibre and/or for extracting from it the optical service signals.

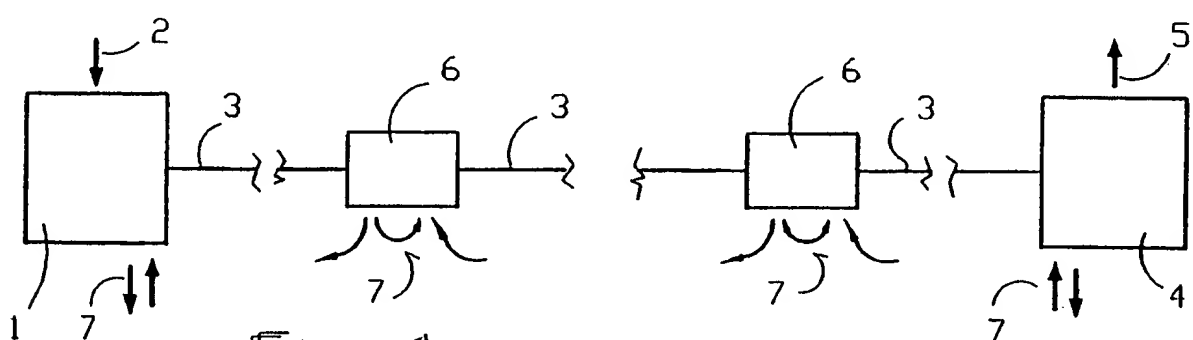

Fig. 1

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OPTICAL FIBRE TELECOMMUNICATIONS LINE WITH SEPARATE SERVICE CHANNELS.

The present invention relates to an optical fibre telecommunications line, provided with an independent channel for service communications.

Communications lines, suitable for allowing the transmission of communications over great distances, in addition to the channels used for communications signals, placed at the disposal of subscribers, usually also provide for an independent channel, suitable for allowing the transmission of service communications.

Such service signals can be of different kinds, say control or command signals for equipment located along the line, such as amplifiers or repeaters, or communications between maintenance staff, operating at a point along the line, and an intermediate or end station of the line itself.

In an optical fibre telecommunications line, provided at regular intervals with repeaters for the amplification of the transmitted signals, one or more of the communications channels may be used for the service signals, which are accessible, for sending or receiving service signals, at each repeater, where the optical signals are detected and transformed into electrical signals, electronically amplified and once again sent towards the destination station, in an optical form.

In such repeaters a service signal converted into an electrical form can be easily received and used for the desired purposes and in a similar manner a signal may be injected in an electric form into the repeater and then converted into an optical signal together with the other signals subjected to amplification and sent along the line.

However, optical fibre telecommunication lines have currently proved convenient which, instead of repeaters, of an electronic type, use optical amplifiers, in a position of amplifying the signal without converting it into an electrical form.

In such lines it is not possible for signals to be injected into or to extracted from the fibre along which they are transmitted with the known electronic equipment, because the signals are available only in an optical form, even at the amplifiers.

The problem therefore arises of injecting into and extracting from an optical telecommunications line, possibly provided with optical amplifiers, the service signals, by operating on the signals themselves in an optical form.

There are known devices called optical couplers, suitable for injecting into or for extracting from an optical fibre signals having a wavelength different from that of the other signals, which pass unaltered, but, in order for such couplers do operate correctly, with a complete separation between the extracted signals and the unaltered signals and with a reduced attenuation of the signals themselves, they must operate between wavelengths that are substantially different, while optical communications are accomplished in a fairly narrow range of wavelengths, where the transmission characteristics of the fibre are better.

The object of the present invention is thus to provide an optical fibre transmission line where it is possible to inject and extract service optical signals, without having to convert the transmitted signals into an electrical form.

The object of the present invention is an optical fibre transmission line, comprising at least one emission station and one reception station of telecommunications signals and at least one optical amplifier, characterized in that it comprises means for injecting and means for extracting optical service signals from the line's optical fibre, where said means comprise at least one emission and/or reception unit of optical service signals, suitable for receiving from the optical line and/or emitting towards the same service signals, constituted by communication or control signals electrically supplied by or taken from the unit itself, in the form of optical signals having a wavelength which is substantially different from the wavelength of the telecommunications signals, where said unit is associated with a corresponding optical coupler inserted along the line, suitable for coupling within the line fibre and/or for extracting from it the optical service signals, with the optical amplifier or with each optical amplifier there being associated at least one means for injecting or extracting optical service signals.

Preferably the optical amplifier or each optical amplifier is associated with a means for injecting and with a means for extracting service optical signals, suitable for switching the service signals themselves along a path external to the amplifier.

The wavelength of the service signals is substantially equal to or differs only slightly from the wavelength corresponding to a minimum of the attenuation curve of the light in the optical fibre in relation to the wavelength.

Conveniently such wavelength of the telecommunications signals ranges substantially from 1500 to 1600 nm and the wavelength of the service signals ranges from 1200 to 1400 nm, said service signals being transmitted at a rate substantially lower than 300 Kbit/sec.

Preferably the optical couplers are constituted by dichroic fibre couplers.

In greater detail, in such a preferred embodiment the line optical amplifier or amplifiers are constituted by sections of active fibre, doped with

fluorescent substances and by means for injecting into the sections of active fibre luminous pumping energy, having a wavelength different from the telecommunications wavelength, generated by respective pumping lasers, there being present at at least one amplifier a reception unit and an emission unit of service optical signals and corresponding optical couplers inserted along the line fibre, upstream and downstream from the optical amplifier, respectively, in the direction in which the service signals are to be sent.

Conveniently the reception and emission units are connected together electrically, with the possible interposition of electronic amplification means, said units being suitable for receiving optical service signals from the line, for transforming them into electrical signals, for amplifying them electronically and respectively for receiving the amplified electrical signals, for converting them into optical signals at the service wavelength and for sending them along the line; the reception and emission units of the service signals comprise means for the control and command of the amplifier' s pumping laser or lasers, driven by the service signals.

In a preferred embodiment of the invention the means for injecting luminous pumping energy into the active fibre sections of at least one optical amplifier and one optical coupler of the service signals at the amplifier itself are constituted by a single three-wavelength optical coupler.

Greater details can be seen from the following description of the invention, with reference to the enclosed drawings, which show:

- in Fig. 1, a diagram of an optical fibre telecommunications line, with line amplifiers;
- in Fig. 2, a diagram of an optical fibre telecommunications line, with line amplifiers, provided with inputs and outputs for service communications;
- in Fig. 3, a diagram of an optical amplifier for a telecommunications line, provided with inputs and outputs for service channels according to the invention;
- in Fig. 4, a diagram of an optical amplifier for a telecommunications line, provided with inputs and outputs for service channels according to the invention, in a particular embodiment;
- in Fig. 5, a diagram of the curve of the light attenuation in a silica optical fibre, in relation to the wavelength of the injected light.

As shown by Fig. 1, a telecommunications line of the optical type comprises in general a station 1 for the mission of optical signals, wherein the signals 2 to be transmitted are received, usually in the form of electrical signals, and emitted in an optical form injected into an optical fibre 3, constituting the line.

At the opposite end of fibre 3, at a great distance from the emission station 1, even of the order of hundreds of kilometres, there is a reception station 4, suitable for receiving the optical signals transmitted along the fibre, for converting them into signals of another nature, say electrical signals, and for sending such signals 5 to the reception equipment, not shown.

The emission and reception stations are known in themselves and shall not be described further.

Along the fibre 3, due to the attenuations to which the optical signal is inevitably subjected in its path along the fibre itself, there are line amplifiers 6, suitable for receiving the optical signal attenuated after a certain length of fibre and for emitting it after having restored it to the original level, to allow it to pass along a further fibre section, up to a new amplifier or up to the receiving station, maintaining itself to destination at a level which will allow it to be received correctly.

A telecommunications line, operating over great distances, comprises a certain number of amplifiers, in relation to the overall distance to be covered, to the fibre's attenuation, to the gain of the amplifiers and to the minimum level acceptable for the signal at reception.

The amplifiers 6, of whatever type they may be, provide in general for the reception and/or emission of control signals, say for the activation or the check of the operation of some of their components, and, in addition, are subjected to maintenance activities for which an operator may have to communicate with the terminal emission or reception stations, or with other line amplifiers.

In all these cases it is thus required to introduce into the communication line further signals 7, which may be received and injected at any line amplifier or at the terminal stations.

In the case wherein the line amplifiers are repeaters, which thus receive optical signals travelling on the line, convert them into an electrical form, amplify them electronically and retransmit them in an optical form into the subsequent line section, the service signals may be of the same type as the communications signals and recognised by and separated from the same, or they may be introduced into the line, when all the signals are converted in an lectrical form in the amplifiers or in the terminal stations, to be used as required.

In optical fibre telecommunications lines there is, however, convenient use for amplifiers of the optical type, wherein the signals are amplified while

remaining in an optical form; in such cases, therefore, it is not possible by electronic means for separating the service signals from the communication signals travelling in the same fibre without interrupting the fibre itself.

For such purpose according to the invention, as illustrated by Fig. 2, at each optical amplifier 8, generically represented in the figure, there are, upstream and downstream from the same, two dichroic couplers 9, suitable for receiving in a common input the communication signals and the service signals, having wavelengths that are different and multiplexed on the same fibre and for separating at output on two outgoing fibres 9a and 9b the communication signals at one wavelength and the service signals at a different wavelength, respectively, and also suitable for sending in a single outgoing fibre the communication signals and the service signals separately injected into fibres 9a and 9b.

Similar dichroic couplers are present at the emission and reception stations 1, 4.

In order to accomplish the separation between the signals by means of dichroic couplers, the wavelength of the service signals is selected to be appreciably different from that of communication.

The communication wavelength usually ranges from 1500 to 1600 nm, in an area called third window, so as to operate at the minimum of the light attenuation in silica glass fibres, as illustrated in the diagram of Fig. 6; as required for telecommunications, this allows the transmission of data at high speed, of the order of several hundred Mbit/sec, over distances of tens or hundreds of kilometres before amplification, maintaining the signals at levels sufficient for a correct final reception.

The service signals, on the other hand, in view of their characteristics, can be transmitted at low speed, of the order of some hundreds of Kbit/sec, in particular below 300 Kbit/sec; according to the invention such service signals are then emitted at a wavelength around 1300nm, at a secondary minimum of the light attenuation curve in silica glass, called second window.

In the following text, the words around 1300 nm shall mean a wavelength in the wavelength range typical of the above mentioned second window, where there is a relatively low attenuation; the amplitude of such range depends on the specific characteristics of the line fibre used; a preferred range, for commonly produced line fibres, can be from 1200 to 1400 nm.

The light attenuation at such wavelength is appreciably higher than at 1500-1600 nm, and would not allow the coverage of the distance between two successive amplifiers with an arrival level acceptable for the reception equipment suitable for operation at the transmission speeds used for the communication signals indicated above; but the service signals, on the other hand, transmitted at lower speeds (typically 128 Kbit/sec, can be received by very sensitive receivers and thus a wavelength around 1300 nm is acceptable for them.

This makes it possible to use commercially produced dichroic couplers, such as fibres that are fused or accomplished in micro-optics, having excellent features in terms of attenuation and limited cost.

Each dichroic coupler 9 is connected, with the corresponding outgoing fibre 9b carrying the service signals, to a respective connecting unit 10, through which the service signals leaving the coupler are received and converted into corresponding output electrical signals, and input electrical signals are converted into optical signals at the service wavelength and injected at the input into the fibre 9b to be multiplexed along the line.

In this way an optical signal, at 1300 nm, extracted from line 3 by dichroic coupler 9, is transformed into a corresponding electrical signal, which may be used for the purposes provided for it, such as, say, service telephone communications of maintenance or control personnel of optical amplifier 8, as represented by dotted lines in Fig. 2, or for further commands or controls; in a similar manner, electrical control signals or service telephone communications can be sent along fibre 3 of the line to reach other destinations.

To allow the service signals to reach amplifiers or terminal stations located at a great distance from the place at which the signal is emitted, along a fibre having several optical amplifiers, the electrical signal in output from a unit 10 connected to a dichroic coupler 9, located upstream from an optical line amplifier 8, is electronically amplified, in a known manner, by a corresponding service amplifier 11 and then sent to the input of a unit 10 connected to a second dichroic coupler 9, downstream from the optical amplifier, suitable for sending the appropriately amplified service signal along the subsequent optical fibre section, up to the destination station or to a new optical amplifier.

In this way the service signal is amplified autonomously, at each optical amplifier of the line and can thus travel along the entire distance required and arrive at destination at a level sufficient for the purposes assigned to it.

Fig. 3 shows in greater detail an embodiment of the invention, which shows an optical amplifier 8 which comprises an active optical fibre 12, having a suitable length, doped with a fluorescent substance, a pumping laser 13, connected to a corresponding dichroic coupler 14, suitable for sending inside the active fibre luminous energy suitable for producing a stimulated emission inside the fibre

itself, which generates the requested amplification.

Preferably, but not necessarily, there can also be a second pumping laser 13' and a corresponding dichroic coupler 14', arranged at the opposite end of the active fibre 12 with respect to coupler 14 and mirror oriented, with the purpose of enhancing the pumping power inside the active fibre and/or constituting a pumping means of the active fibre held in reserve in case of malfunction of the first pumping laser 13.

In must in any case be observed that the possible presence of the second pumping laser 13' and of the coupler 14' is substantially non-influent, in this embodiment, for the purpose of transmitting service signals along the optical line according to the present invention.

As already illustrated with reference to Fig. 2, amplifier 8 is preceded and followed by the dichroic couplers 9, connected to their respective service signals reception and transmission units 10. The lasers 13 and 13' are connected, as represented by the dotted lines, to units 10 and can thus receive or send control or similar signals which govern their operation.

Fig. 4 shows a particular embodiment of the invention, in which there are two pumping lasers, 13 and 13' and each of them, together with a reception or transmission unit 10, is connected to a single three-wavelength optical coupler 15, so that the pumping laser sends the corresponding luminous energy towards the active fibre 12, while the reception and transmission unit 10 receives service signals, separate from the optical fibre 3 of the line, before they arrive at the active fibre itself and/or injects service signals into fibre 3 after the active fibre.

In greater detail, as schematically indicated in Fig. 4 by the arrows designated with Sc, Ss, Sp, respectively, each dichroic coupler 15 is in the position of allowing the communication signal Sc, at the communications wavelength (1500-1600 nm), carried by line fibre 3 to the coupler's input connection 16, to be emitted unaltered at the output connection 17, to which the amplifier's active fibre 12 is connected; the service signal Ss, at the service wavelength (1300 nm), present at input connection 16, is addressed to the coupler's output connection 18, to which unit 10 is connected (and vice versa, a signal emitted by unit 10, carried as an input to connection 18 is sent, along the same optical path, as an output to connection 16); the pumping signal Sp, at the pumping wavelength, is sent by pumping laser 13 or 13' as an input to connection 19 and is sent as an output to connection 17.

Three-wavelength optical couplers having the indicated characteristics, constituted by a single monolithic element, say, of the fused fibre type, are known and their accomplishment is made easy and sufficiently inexpensive when the wavelengths to be coupled are appreciably separated one from the other: say, in combination with a communication signal wavelength around 1550 nm a service signal wavelength is used around 1300 nm, as described above and, in the case of an active amplification fibre doped with Erbium, a pumping wavelength of 980 or 530 nm.

Such an accomplishment offers the considerable advantage of accomplishing, with the same component, both the sending of the pumping energy in the amplification fibre, and the extraction or the sending of the service signals in the line fibre, simplifying the amplifier structure and especially reducing the number of junctions between fibres and couplers, each of which is the cause of attenuation for the transmitted signal.

In case the use of the second pumping laser 13' is not desired, in place of one of the three-wavelength couplers 15, to which such laser should have been connected, it is possible to use a dichroic coupler 9, as described previously, merely for the connection of the service reception and transmission unit 10.

Although the injection into and the extraction from the optical line of the service signals is conveniently executed at the line's end stations and at the line amplifiers, as described previously, it is possible to introduce dichroic couplers and service signal reception and transmission stations at any other position of the optical fibre line where its need may be felt.

In the case of particular requirements of the line or in the structure of the couplers, a wavelength may be adopted, for the service signals, other than that around 1300 nm indicated previously, accepting the signal attenuation level which corresponds to the selected wavelength.

In addition, within the scope of the present invention, in the presence of fibres having particular transmission characteristics, instead of the wavelength around 1300 nm, in the sense previously defined, a different wavelength, or a different range of wavelengths, may be adopted for the service signals, corresponding to a relative attenuation minimum, or in any case to a sufficiently low attenuation value, in relation to the power and to the sensitivity of the transmission and reception equipment, as long as it is sufficiently far from the range of transmission wavelengths as to allow the accomplishment of the corresponding optical couplers.

For the purpose of the present invention it is intended that line end stations are two points of the line itself between which the signals travel solely in an optical form, amplified where necessary by optical amplifiers of the type described above.

Many variants can be introduced in the future, without going beyond the scope of the present invention in its general characteristics.

Claims

1. Optical fibre transmission line, comprising at least one emission station (1) and one reception station (4) of telecommunications signals and at least one optical amplifier (6, 8), characterized in that it comprises means (9, 10) for injecting and means (9, 10) for extracting optical service signals from the line' s optical fibre (3), where said means comprise at least one emission and/or reception unit (10) of optical service signals, suitable for receiving from the optical line and/or emitting towards the same service signals, constituted by communication or control signals electrically supplied by or taken from the unit itself, in the form of optical signals having a wavelength which is substantially different from the wavelength of the telecommunications signals, where said unit (10) is associated with a corresponding optical coupler (9) inserted along the line, suitable for coupling within the line fibre (3) and/or for extracting from it the optical service signals, with the optical amplifier (6, 8) or with each optical amplifier there being associated at least one means (9, 10) for injecting or extracting optical service signals.

2. Optical fibre transmission line according to claim 1, characterized in that the optical amplifier (6, 8) or each optical amplifier is associated with a means (9, 10) for injecting and with a means (9, 10) for extracting optical service signals, suitable for switching the service signals themselves along a path external to the amplifier (8).

3. Optical fibre transmission line according to claim 1, characterized in that the wavelength of the service signals is substantially equal to or differs only slightly from the wavelength corresponding to a minimum of the attenuation curve of the light in the optical fibre in relation to the wavelength.

4. Optical fibre transmission line according to claim 1, characterized in that the wavelength of the telecommunications signals ranges substantially from 1500 to 1600 nm and the wavelength of the service signals ranges from 1200 to 1400 nm, said service signals being transmitted at a rate substantially lower than 300 Kbit/sec.

5. Optical fibre transmission line according to claim 1, characterized in that the optical couplers (9) are constituted by by dichroic fibre couplers.

6. Optical fibre transmission line according to claim 2, characterized in that the line optical amplifier (6, 8) or amplifiers are constituted by sections of active fibre (12), doped with fluorescent substances and by means (14) for injecting into the sections of active fibre (12) luminous pumping energy, having a wavelength different from the telecommunications wavelength, generated by respective pumping lasers (13), there being present at at least one amplifier a reception unit (10) and an emission unit (10) of service optical signals and corresponding optical couplers (9) inserted along the line fibre (3), upstream and downstream from the optical amplifier (8), respectively, in the direction in which the service signals are to be sent.

7. Optical fibre transmission line according to claim 6, characterized in that the reception and emission units (10) are connected together electrically, with the possible interposition of electronic amplification means (11), said units being suitable for receiving optical service signals from the line (3), for transforming them into electrical signals, for amplifying them electronically and respectively for receiving the amplified electrical signals, for converting them into optical signals at the service wavelength and for sending them along the line.

8. Optical fibre transmission line according to claim 6, characterized in that the reception and emission units (10) of the service signals comprise means for the control and command of the amplifier' s pumping laser or lasers (13), driven by the service signals.

9. Optical fibre transmission line according to claim 6, characterized in that the means (15) for injecting luminous pumping energy into the active fibre sections of at least one optical amplifier and one optical coupler of the service signals at the amplifier itself are constituted by a single three-wavelength optical coupler (15).

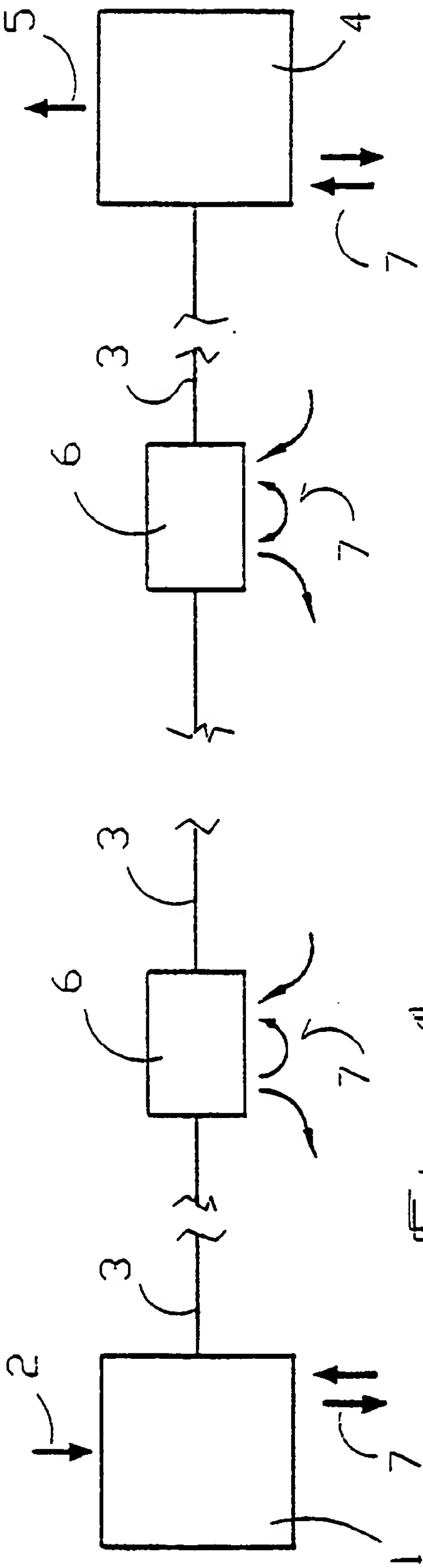

Fig. 1

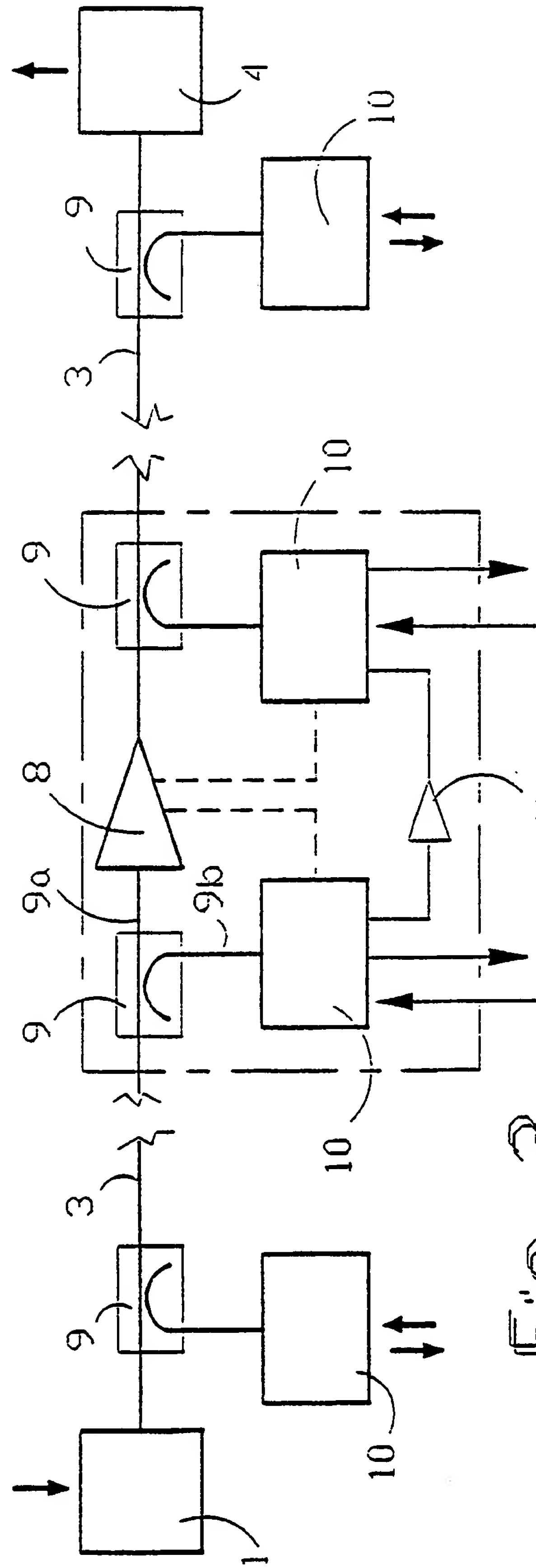

Fig. 2

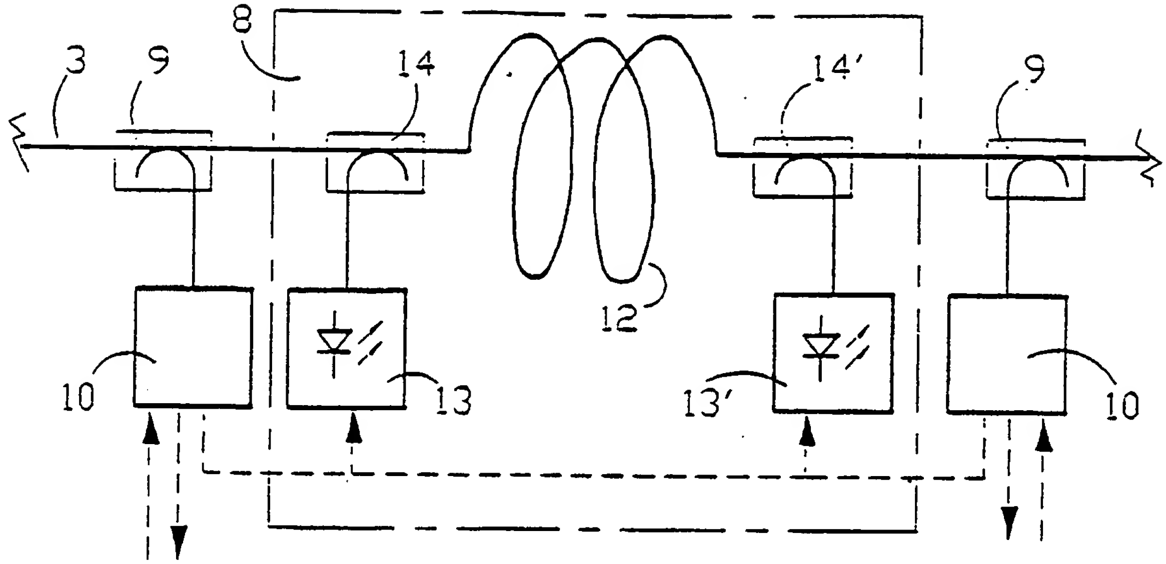

Fig. 3

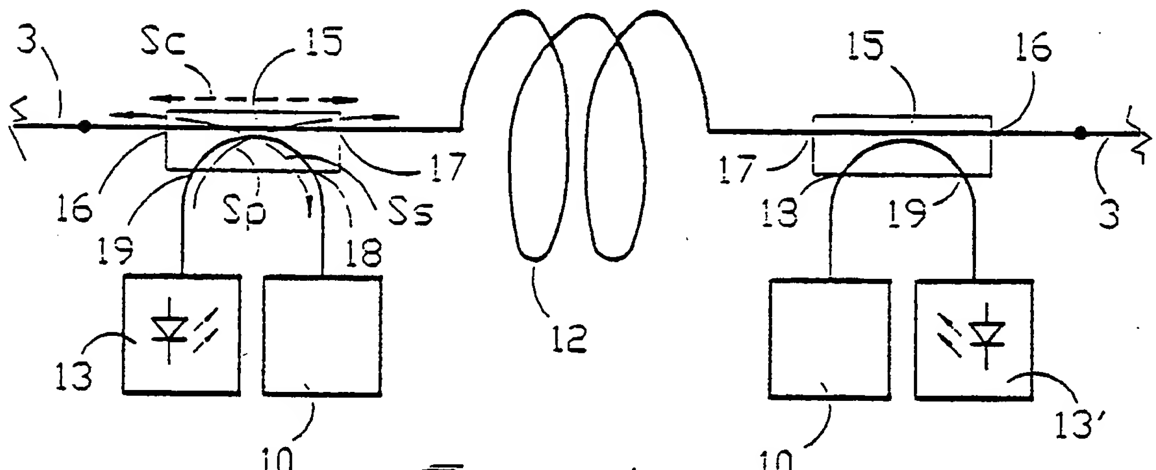

Fig. 4

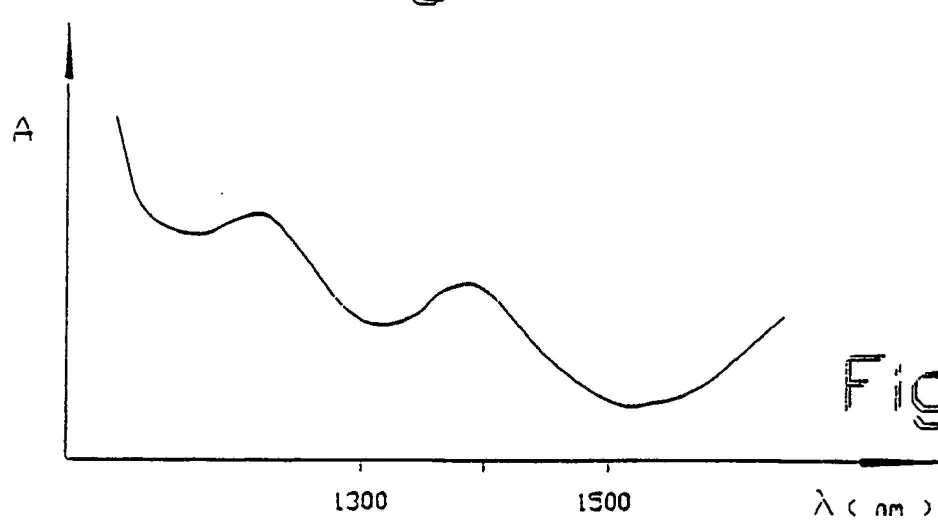

Fig. 5